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JC813 U.S. PTO 08/16/00

PATENT APPLICATION TRANSMITTAL LETTER
(Small Entity)

Docket No. 56230-014

TO THE ASSISTANT COMMISSIONER FOR PATENTS

JC542 U.S. PTO 09/640246 08/16/00

Transmitted herewith for filing under 35 U.S.C. 111 and 37 C.F.R. 1.53 is the patent application of:

Dino J. Farina

For: **SPRAY DATA ACQUISITION SYSTEM**

Enclosed are:

- ☒ Certificate of Mailing with Express Mail Mailing Label No. **EL543282316US**
- ☒ **Three (3)** sheets of drawings.
- ☐ A certified copy of a application.
- ☒ Declaration ☐ Signed. ☒ Unsigned.
- ☒ Power of Attorney
- ☐ Information Disclosure Statement
- ☐ Preliminary Amendment
- ☒ **Unexecuted** Verified Statement(s) to Establish Small Entity Status Under 37 C.F.R. 1.9 and 1.27.
- ☒ Other: **acknowledgement postcard**

CLAIMS AS FILED

For	#Filed	#Allowed	#Extra	Rate	Fee
Total Claims	13	- 20 =	0	x $9.00	$0.00
Indep. Claims	2	- 3 =	0	x $39.00	$0.00
Multiple Dependent Claims (check if applicable) ☐					$0.00
				BASIC FEE	$380.00
				TOTAL FILING FEE	$380.00

- ☒ A check in the amount of **$380.00** to cover the filing fee is enclosed.
- ☒ The Commissioner is hereby authorized to charge and credit Deposit Account No. **50-1133** as described below. A duplicate copy of this sheet is enclosed.
  - ☐ Charge the amount of as filing fee.
  - ☒ Credit any overpayment.
  - ☒ Charge any additional filing fees required under 37 C.F.R. 1.16 and 1.17.
  - ☐ Charge the issue fee set in 37 C.F.R. 1.18 at the mailing of the Notice of Allowance, pursuant to 37 C.F.R. 1.311(b).

Dated: **August 16, 2000**

Signature

Ronald R. Demsher
Registration No. 42,478

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Boston, Massachusetts 02109
Tel. 617-535-4000
Fax: 617-535-3800

cc:

CERTIFICATE OF MAILING BY "EXPRESS MAIL" (37 CFR 1.10) Applicant(s): **Dino J. Farina**			Docket No. **56320-014**
Serial No.	Filing Date **herewith**	Examiner **not yet assigned**	Group Art Unit **not yet assigned**

Invention: **SPRAY DATA ACQUISITION SYSTEM**

I hereby certify that the following correspondence:

Patent Application Transmittal Letter (Small Entity); (unexecuted) Declaration and Power of Attorney for Patent Application; Application (16 sheets); Drawings (3 sheets, Figs. 1-3); check for $380; and return postcard

(Identify type of correspondence)

is being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 CFR 1.10 in an envelope addressed to: The Assistant Commissioner for Patents, Washington, D.C. 20231 on

August 16, 2000
(Date)

Roberta L. Hahn
(Typed or Printed Name of Person Mailing Correspondence)

Roberta L. Hahn
(Signature of Person Mailing Correspondence)

EL543282316US
("Express Mail" Mailing Label Number)

Note: Each paper must have its own certificate of mailing.

VERIFIED STATEMENT (DECLARATION) CLAIMING SMALL ENTITY STATUS (37 CFR 1.9(f) AND 1.27 (c)) - SMALL BUSINESS CONCERN	Docket No. 56320-014

Serial No.	Filing Date	Patent No.	Issue Date

Applicant/ Patentee: **Dino J. Farina**

Invention: **SPRAY DATA ACQUISITION SYSTEM**

I hereby declare that I am:

- ☐ the owner of the small business concern identified below:
- ☒ an official of the small business concern empowered to act on behalf of the concern identified below:

NAME OF CONCERN: **Image Therm Engineering**

ADDRESS OF CONCERN: **142 North Road, Suite 100, Sudbury, Massachusetts 01776**

I hereby declare that the above-identified small business concern qualifies as a small business concern as defined in 13 CFR 121.3-18, and reproduced in 37 CFR 1.9(d), for purposes of paying reduced fees under Section 41(a) and (b) of Title 35, United States Code, in that the number of employees of the concern, including those of its affiliates, does not exceed 500 persons. For purposes of this statement, (1) the number of employees of the business concern is the average over the previous fiscal year of the concern of the persons employed on a full-time, part-time or temporary basis during each of the pay periods of the fiscal year, and (2) concerns are affiliates of each other when either, directly or indirectly, one concern controls or has the power to control the other, or a third party or parties controls or has the power to control both.

I hereby declare that rights under contract or law have been conveyed to and remain with the small business concern identified above with regard to the above identified invention described in:

- ☐ the specification filed herewith with title as listed above.
- ☒ the application identified above.
- ☐ the patent identified above.

If the rights held by the above-identified small business concern are not exclusive, each individual, concern or organization having rights to the invention is listed on the next page and no rights to the invention are held by any person, other than the inventor, who could not qualify as an independent inventor under 37 CFR 1.9(c) or by any concern which would not qualify as a small business concern under 37 CFR 1.9(d) or a nonprofit organization under 37 CFR 1.9(e).

Each person, concern or organization to which I have assigned, granted, conveyed, or licensed or am under an obligation under contract or law to assign, grant, convey, or license any rights in the invention is listed below:

☒ no such person, concern or organization exists.
☐ each such person, concern or organization is listed below.

FULL NAME _____
ADDRESS _____
☐ Individual ☐ Small Business Concern ☐ Nonprofit Organization

FULL NAME _____
ADDRESS _____
☐ Individual ☐ Small Business Concern ☐ Nonprofit Organization

FULL NAME _____
ADDRESS _____
☐ Individual ☐ Small Business Concern ☐ Nonprofit Organization

FULL NAME _____
ADDRESS _____
☐ Individual ☐ Small Business Concern ☐ Nonprofit Organization

Separate verified statements are required from each named person, concern or organization having rights to the invention averring to their status as small entities. (37 CFR 1.27)

I acknowledge the duty to file, in this application or patent, notification of any change in status resulting in loss of entitlement to small entity status prior to paying, or at the time of paying, the earliest of the issue fee or any maintenance fee due after the date on which status as a small entity is no longer appropriate. (37 CFR 1.28(b))

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this verified statement is directed.

NAME OF PERSON SIGNING: **Dino J. Farina**

TITLE OF PERSON SIGNING OTHER THAN OWNER: **President**

ADDRESS OF PERSON SIGNING: **159 Summer St.**
Waltham, Massachusetts 02154

SIGNATURE: _____ DATE: _____

Draft: ITED-110

APPLICATION

FOR

UNITED STATES LETTERS PATENT

SPECIFICATION

TO ALL WHOM IT MAY CONCERN:

Be it known that Dino J. Farina, a U.S. citizen, residing in Waltham, MA, has invented certain improvements in a SPRAY DATA ACQUISITION SYSTEM of which the following description in connection with the accompanying drawings is a specification, like reference characters on the drawings indicating like parts in the several figures.

SPRAY DATA ACQUISITION SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of United States Provisional Application Number 60/149,281, filed August 17, 1999, the contents of which are incorporated herein by reference in their entirety, and from which priority is claimed.

This application is related to the following U.S. application filed contemporaneously herewith, of common assignee, the contents of which are incorporated herein in their entirety by reference:

"SPRAY DATA ANALYSIS AND CHARACTERIZATION SYSTEM," invented by Dino J. Farina, U.S. Patent Application Serial Number _____, Attorney Docket No. ITED-113.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH

Not Applicable

REFERENCE TO MICROFICHE APPENDIX

Not Applicable

BACKGROUND OF THE INVENTION

The present invention relates to systems for and methods of characterizing aerosol spray patterns, and more particularly, to systems and methods that illuminate an aerosol spray plume and utilize optical techniques to characterize the associated spray pattern.

The fluid dynamic characterization of the aerosol spray emitted by metered nasal spray pumps and metered dose inhalers is crucial in determining the overall performance of the inhaler as a drug delivery device ("DDD"). In addition to treating direct respiratory ailments, inhaler-based DDDs are now increasingly being used to deliver drugs such as flu vaccines, insulin and migraine headache relievers because they deliver their dose of medication to tissues that can more efficiently absorb the drug and bring

relief to patients more conveniently. Spray characterization is also an integral part of the regulatory submissions necessary for Food and Drug Administration ("FDA") approval of research and development, quality assurance and stability testing procedures for new and existing inhaler-based DDDs.

Thorough characterization of the spray's geometry has been found to be the best indicator of the overall performance of most inhaler-based DDDs. In particular, measurements of the spray's divergence angle (plume geometry) as it exits the device; the spray's cross-sectional ellipticity,uniformity and particle/droplet distribution (spray pattern); and the time evolution of the developing spray have been found to be the most representative performance quantities in the characterization of an inhaler-based DDD.

During research and development, these measurements are typically used to optimally match the spray pump's performance characteristics with the fluid properties of the liquid/solid medicine solution, resulting in a more cost-effective and efficient product design. However, accurate, reliable and easy-to-use protocols and a system for inhaler-based DDDspray characterization do not exist. During quality assurance and stability testing, plume geometry and spray pattern measurements are key identifiers for verifying consistency and conformity with the approved data criteria for the inhaler-based DDD.

The currently adopted inhaler spray testing standard that is in use today at pharmaceutical companies involves firing the spray pump at a solid, thin-layer chromatography ("TLC") plate having a coating that fluoresces in response to incident ultraviolet ("UV") radiation. The TLC plate is positioned at a fixed height above the exit port of the pump. The pattern of the spray deposited on the plate is then analyzed.

In a conventional test configuration, the analysis of an exposed plate begins with illumination of the plate with UV radiation. The incident UV radiation causes the plate's coating to fluoresce and helps to highlight the outline of the spray pattern. Marking instruments and mechanical calipers are then used to draw and measure an outline of the deposited patterns on the plate. Measurements of the spray pattern's ellipticity in terms of major- and minor-diameters are recorded.

One disadvantage to this configuration is that the presence of the TLC plate

radically alters the natural fluid dynamics of the spray causing it to switch from a free aerosol jet to an impinging jet.

Another disadvantage to this configuration is that a large of amount of the spray particles bounce off the plate, causing artifacts in the pattern that do not exist in an unconstrained spray. This is especially problematic for dry powder-based DDDs because the particles don't tend to stick to the TLC plate at all causing artificially low spray pattern densities to be measured and reported.

Yet another disadvantage to this configuration is that the measurements of the spray pattern are very sensitive to the operator's judgement and prone to low reliability.

A further disadvantage to this configuration is that the associated measurement technique is restricted to measurements only of the static aspects of the spray pattern; it cannot be used to investigate any time-evolving or plume geometry properties of the spray.

It is an object of the present invention to substantially overcome the above-identified disadvantages and drawbacks of the prior art.

SUMMARY OF THE INVENTION

In one preferred embodiment, the invention provides a device for producing image data representative of at least one sequential set of images of a spray plume. Each of the images is representative of a density characteristic of the spray plume (i) along a geometric plane that intersects the spray plume, and (ii) at a predetermined instant in time. The device includes an illuminator for providing an illumination of the spray plume along at least one geometric plane that intersects the spray plume. The device also includes a transducer for generating the image data representative of an interaction between the illumination and the spray plume along the geometric plane.

The foregoing and other objects are achieved by the invention which in one aspect comprises a spray data acquisition system that includes a housing for supporting a pumping device. The pumping device is responsive to an applied force to generate an

aerosol spray plume through an exit port thereon along a spray axis. The system further includes a spray pump actuator that is capable of controlling the pumping force and the duration of the aerosol spray plume produced by the pumping device. The system also includes an illumination device that illuminates the aerosol spray plume along at least one first geometric plane that intersects the aerosol spray plume. The system further includes an imaging device that acquires data representative of an interaction between the illumination and the aerosol spray plume along at least one geometric plane.

In another aspect, the invention comprises an apparatus for producing image data representative of at least one sequential set of images of a spray plume. Each of the images is representative of a density characteristic of the spray plume (i) along a geometric plane that intersects the spray plume, and (ii) at a predetermined instant in time. The apparatus includes an illuminator for providing an illumination of the spray plume along at least one geometric plane that intersects the spray plume. The apparatus further includes a transducer for generating the image data representative of an interaction between the illumination and the spray plume along the at least one geometric plane.

In another embodiment of the invention, the sequential set of images is representative of a progression in time.

In another embodiment of the invention, a first time-sequential set of images corresponds to an axial cross-sectional density characteristic along a first geometric plane substantially normal to a flow direction centerline, and a second time-sequential set of images corresponds to a longitudinal density characteristic along a second geometric plane substantially parallel to and intersecting the flow direction centerline.

In another embodiment of the invention, the interaction between the illumination and the spray plume includes optical scattering.

In another embodiment of the invention, the interaction between the illumination and the spray plume includes optical absorption.

In another embodiment of the invention, the transducer includes a digital imaging system for generating and recording the image data.

In another embodiment of the invention, the digital imaging system includes an

image sampling rate of approximately 500 images per second.

In another embodiment of the invention, the illuminator includes a laser system having a fan-shaped output pattern.

In another embodiment of the invention, the fan-shaped output pattern includes a fan angle of approximately 45 degrees, and a laser line thickness of approximately one millimeter, measured at the centerline of the spray.

In another embodiment of the invention, the laser system includes a 4 watt, 810 nm laser output.

In another embodiment of the invention, the illumination device illuminates the spray plume along a second geometric plane that intersects the aerosol spray plume, and the imaging device acquires data representative of a second interaction between the illumination and the aerosol spray plume along a second geometric plane. In one embodiment, the first and the second geometric planes are substantially orthogonal.

BRIEF DESCRIPTION OF DRAWINGS

The foregoing and other objects of this invention, the various features thereof, as well as the invention itself, may be more fully understood from the following description, when read together with the accompanying drawings in which:

FIG. 1 is a schematic showing a spray data acquisition system, according to an embodiment of the invention;

FIG. 2. shows an illumination device illuminating a transverse axial cross-sectional slice of a spray in the embodiment of FIG. 1; and

FIG. 3 shows an illumination device illuminating a slice of a spray along the spray axis in the embodiment of FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The spray data acquisition system of the present invention provides images of the time-evolution, particle distribution, and divergence angle of aerosol sprays. The spray

data acquisition system is a non-intrusive, optical-based design system that is capable of capturing information representative of the time evolution of an aerosol spray for substantially complete geometrical (divergence angle and plume geometry) and pattern (cross-sectional uniformity and ellipticity) imaging. The modular hardware of the system allows easy customization to meet the needs of a variety of spray testing applications in research & development, stability testing and production environments.

FIG. 1 shows a spray data acquisition system 10 which generates data representative of the characteristics of an aerosol spray as emitted from a spray pump 22. The system 10 includes a spray pump housing 21 for the spray pump 22, an actuator 18, an illumination device 26 and an imaging device 12. The spray pump housing 21 is provided to position the spray pump 22 so as to direct an aerosol spray through a port in the housing 21 along a spray axis SA.

The imaging device 12 of the present invention's data acquisition system 10 includes a camera head 14 and a control unit 16. Associated with the actuator 18 is a spray actuator control unit 20 and a force control element 19, responsive to the spray control unit 20, for controlling a pumping force and a duration of an aerosol spray plume of the spray pump 22. The actuator 18 is preferably an electro-mechanical transducer that converts electrical control signals from the control unit 20, although other techniques known in the art for generating a pumping force may also be used, e.g., hydraulic, pneumatic, simple mechanical linkage, etc. The actuator 18 selectively activates the pump 22 to produce a spray plume for evaluation by the system 10. The centerline of the aerosol spray plume is shown as the spray axis SA.

The illumination device 26 is adapted to simultaneously or sequentially illuminate the spray with thin, fan-shaped beams of light along the spray axis SA and transverse to the spray axis SA. The imaging device 12 is adapted to acquire data representative of the optical density distribution of the portions of the spray illuminated by the illumination device 26. A first set of data is generated that is representative of a transverse cross-sectional slice of the spray plume. This set of data is useful in providing information relating to the spray divergence and the degree of spray uniformity in various directions

radiating from the spray axis. A second set of data is generated that is representative of a slice of the spray along the spray axis. This set of data is useful in providing information on the spray divergence and the degree of spray uniformity along the spray axis and other axes diverging from the exit port.

The spray pump actuator 18, the force control element 19 and the control unit 20 are programmable so as to control key parameters associated with aerosol spray pumping, including pumping force and duration. In addition, the actuator 18 includes an output trigger signal that triggers the imaging device when the spray pump is actuated. Since the duration of the spray plume created by a single pumping of the pump 22 is only on the order of one second, it is crucial to have accurate synchronization between the spray pump actuator 18 and the imaging device 12. The InnovaSystems (Pennsauken, NJ) Nasal Spray Pump Actuator is an example of a preferable actuator for use with the present invention. The InnovaSystems actuator includes built-in programmability to control many of the key parameters involved with aerosol spray pumping described herein. In addition, the InnovaSystems actuator is equipped with a digital output signal that can trigger the imaging device when the pump is fired. This signal is compatible with the digital input trigger of the National Instruments PCI-1424 and Dalsa CA-D6-0256 (an example of a preferable image acquisition device 12) and provides nearly perfect synchronization for the system 10.

The imaging device 12 is preferably capable of an image acquisition speed (i.e. framing rate) and spatial resolution to accurately capture the time evolution of a spray for both geometry and pattern testing. The imaging device 12 preferably provides a framing rate in the neighborhood of 1000 frames/second (fps) at a resolution of 256x256 pixels and 8-bit intensity to accurately capture the time evolution of the spray for both the plume geometry and spray pattern testing. Such acquisition speed and spatial resolution values result in an 80 to 100 fold increase in the amount of pertinent information about the complete fluid dynamics of an aerosol spray plume compared to the TLC-plate method currently being used. As described herein, the combination of the PCI-1424 image acquisition board from National Instruments (Austin, TX) and the CA-D6-0256 high

speed digital camera from Dalsa (Waterloo, Ontario, Canada) is an example of a preferable imaging device 12. The CA-D6-0256 has a programmable framing rate from 1 to 955 fps at a resolution of 256×256 pixels with 256 grayscales (8-bit). In addition, the PCI-1424 image acquisition board communicates directly with the camera and is capable of acquiring and displaying these images in a computer-based software system. Additionally, the camera is fitted with a Cinegon lens from Schneider Optics (Hauppauge, NY) that effectively focuses and transmits the laser light being reflected by the particles onto the camera's image sensor. The power and wavelength specification of the preferred illumination device (the Magnum 4000, described herein) matches favorably to the spectral response of the Cinegon lens and the Dalsa CA-D6-0256. Thus, the preferred camera and laser combination produces bright images that clearly show the spray particles.

The illumination device 26 is preferably capable of illuminating time-evolving spray particles at a frame rate of approximately 500 fps. Preferably, the illumination device is a continuous-wave illuminant (but can also be strobed in unison with the image acquisition to provide better freezing of the in-flight particles) such as a laser sheet generator. Furthermore, the light from the illumination device 26 is capable of being shaped into a thin sheet for accurate illumination of the particles for both the spray pattern and divergence angle measurements. Preferably, the illumination device is capable of producing approximately 4W of illumination power and directly projecting a very thin sheet of light at a wavelength of 810 nm with a fan angle of 45° though other fan angles can be used depending on the situation. The Magnum 4000 laser sheet generator from Lasiris (St. Laurent, Quebec, Canada) is an example of a preferred illumination device 26. This solid-state diode laser produces 4W of illumination power and directly projects a very thin sheet of light at a wavelength of 810 nm, and is available with fan angles of 30, 45 and 60°.

In one preferred embodiment, the mechanical mounting hardware for the spray data acquisition system 10 is designed so that spray pump housing, the spray pump actuator 18, the illumination device26 and the imaging device 12 can be precisely,

adjustably positioned and locked in place on a standard 2" thick optics bench. In this embodiment, the hardware also includes a custom designed calibration target to facilitate spatial calibration and perspective correction of the acquired images. In other embodiments, the various components of the spray data acquisition system 10 may be mounted relative to one another via other methods known to those in the art.

The control unit 16 of the imaging device 12 is responsive to the spray actuator control unit 20. In one embodiment, the control unit 16 of the imaging device 12 is connected to a computer system 24 for subsequent computer analysis of information acquired by the imaging device 12, so as to characterize the parameters associated with the spray plume being analyzed. Alternatively, the information gathered from the imaging device 12 can be analyzed according to other methods known to those of ordinary skill in the art.

In operation, the spray pump 22 is filled with test fluid and placed into the mouth of the actuator 18, which has been pre-calibrated for compression force and duration as per standard pharmaceutical spray testing guidelines. The imaging device 12 is set to capture at 500 fps giving a resolution of 256x256 pixels. The input trigger is armed and set to wait for the actuator 18 to fire. The illumination device 26 is turned on and its light sheet is focused to a thickness of approximately 1mm when it illuminates the plane of spray particles.

When the spray data acquisition system 10 is used to conduct spray pattern tests, the illumination device 26 is positioned so that it illuminates in a thin sheet 28 a predetermined, transverse axial cross section of the spray directly downstream of the spray pump tip 30 as shown in FIG. 2. The centerline of the aerosol spray plume is shown as spray axis SA. The imaging device 12 is positioned so that it can view the spray pattern from above at a slight off-axis angle to prevent the spray particles from directly impinging on the imaging device 12 and lens 36. A calibration target 32 is then temporarily placed in the plane of the illumination device's light sheet 28 and the imaging device lens 36 is adjusted until the target 32 comes into focus. An image of the focused target 32 is then captured with the imaging device 12 and can be downloaded to a

computer or analyzed mechanically according to methods known to those of ordinary skill in the art. This target image 32 is used as a basis for calibrating the physical coordinate system of the spray pattern images and to perform the necessary perspective correction to the images to account for the off-axis viewing angle. The target image 32 is then removed from the scene and the trigger 34 is fired on the actuator 18 causing the imaging device 12 to start capturing the time-evolving images of the spray pattern. This takes about 2 seconds. Alternatively, the images can be analyzed according to methods known to those of ordinary skill in the art.

When the spray data acquisition system of the invention is used to conduct spray geometry tests, the illumination device 12 is positioned so that it illuminates a plane of particles parallel to the flow direction along the centerline of the spray or spray axis SA as shown in FIG. 3. The imaging device 12 is positioned perpendicular to the illumination device sheet plane 38. Similar to the spray pattern tests, the calibration target 32 is then temporarily placed in the plane of the sheet 38 of light emitted from the illumination device 26 and the imaging device lens 36 is adjusted until the target 32 comes into focus. Since in this case the imaging device 12 views the scene normally, no perspective correction is necessary so the target image 32 is used solely for calibrating the physical coordinate system of the spray geometry images. Again, the target image32 is then removed from the sceneand the actuator trigger 34 is fired. Alternatively, the images can be analyzed according to methods known to those of ordinary skill in the art.

The SprayVIEW Spray Characterization System User's Guide, Version 1.0, published by Image Therm Engineering, Inc., 1999, is an exemplary User's Manual for a spray data acquisition system according to the present invention. This user's guide is a manual for an entire spray characterization system, including information regarding acquisition, processing, set up, calibration, safety issues, et al. Thus, some of the information in the User's Manual is beyond the scope of this specification.

The invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The present embodiments are therefore to be considered in respects as illustrative and not restrictive, the scope of the invention being

indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning and range of the equivalency of the claims are therefore intended to be embraced therein.

What is claimed is:

1. A spray data acquisition system comprising:

a housing for supporting a pumping device whereby the pumping device is responsive to an applied force to generate an aerosol spray plume through an exit port thereon along a spray axis;

a spray pump actuator, wherein the spray pump actuator is capable of controlling a pumping force and a duration of the aerosol spray plume of the pumping device;

an illumination device for illuminating the aerosol spray plume along at least one geometric plane that intersects the aerosol spray plume; and,

an imaging device for acquiring data representative of a first interaction between the illumination and the aerosol spray plume along the at least one geometric plane.

2. An apparatus for producing image data representative of at least one sequential set of images of a spray plume, each of the images being representative of a density characteristic of the spray plume (i) along a geometric plane that intersects the spray plume, and (ii) at a predetermined instant in time, comprising:

an illuminator for providing an illumination of the spray plume along at least one geometric plane that intersects the spray plume; and,

a transducer for generating the image data representative of an interaction between the illumination and the spray plume along the at least one geometric plane.

3. An apparatus according to claim 2, wherein the sequential set of images is representative of a progression in time.

4. An apparatus according to claim 2, wherein a first time-sequential set of images corresponds to an axial cross-sectional density characteristic along a first geometric plane substantially normal to a flow direction centerline, and a second time-sequential set of images corresponds to a longitudinal density characteristic along a second geometric plane substantially parallel to and intersecting the flow direction centerline.

5. An apparatus according to claim 2, wherein the interaction between the illumination and the spray plume includes optical scattering.

6. An apparatus according to claim 2, wherein the interaction between the illumination and the spray plume includes optical absorption.

7. An apparatus according to claim 2, wherein the transducer includes a digital imaging system for generating and recording the image data

8. An apparatus according to claim 7, wherein the digital imaging system includes an image sampling rate of approximately 500 images per second.

9. An apparatus according to claim 2, wherein the illuminator includes a laser system having a fan-shaped output pattern.

10. An apparatus according to claim 9, wherein the fan-shaped output pattern includes a fan angle of approximately 45 degrees, and a laser line thickness of approximately one millimeter at approximately the centerline of the emitted spray.

11. An apparatus according to claim 9, wherein the laser system includes a 4 watt, 810 nm laser output.

12. A spray data acquisition system according to claim 1, wherein the illumination device illuminates the spray plume along a second geometric plane that intersects the aerosol spray plume, and the imaging device acquires data representative of a second interaction between the illumination and the aerosol spray plume along a second geometric plane.

13. A spray data acquisition system according to claim 12 wherein the first and the second geometric planes are substantially orthogonal.

ABSTRACT

A spray data acquisition system includes a pumping device responsive to an applied force to generate an aerosol spray plume along a spray axis. The system further includes a spray pump actuator that is capable of controlling the pumping force and the duration of the aerosol spray plume produced by the pumping device. The system also includes an illumination device that illuminates the aerosol spray plume along at least one first geometric plane that intersects the aerosol spray plume. The system further includes an imaging device that acquires data representative of an interaction between the illumination and the aerosol spray plume along at least one geometric plane.

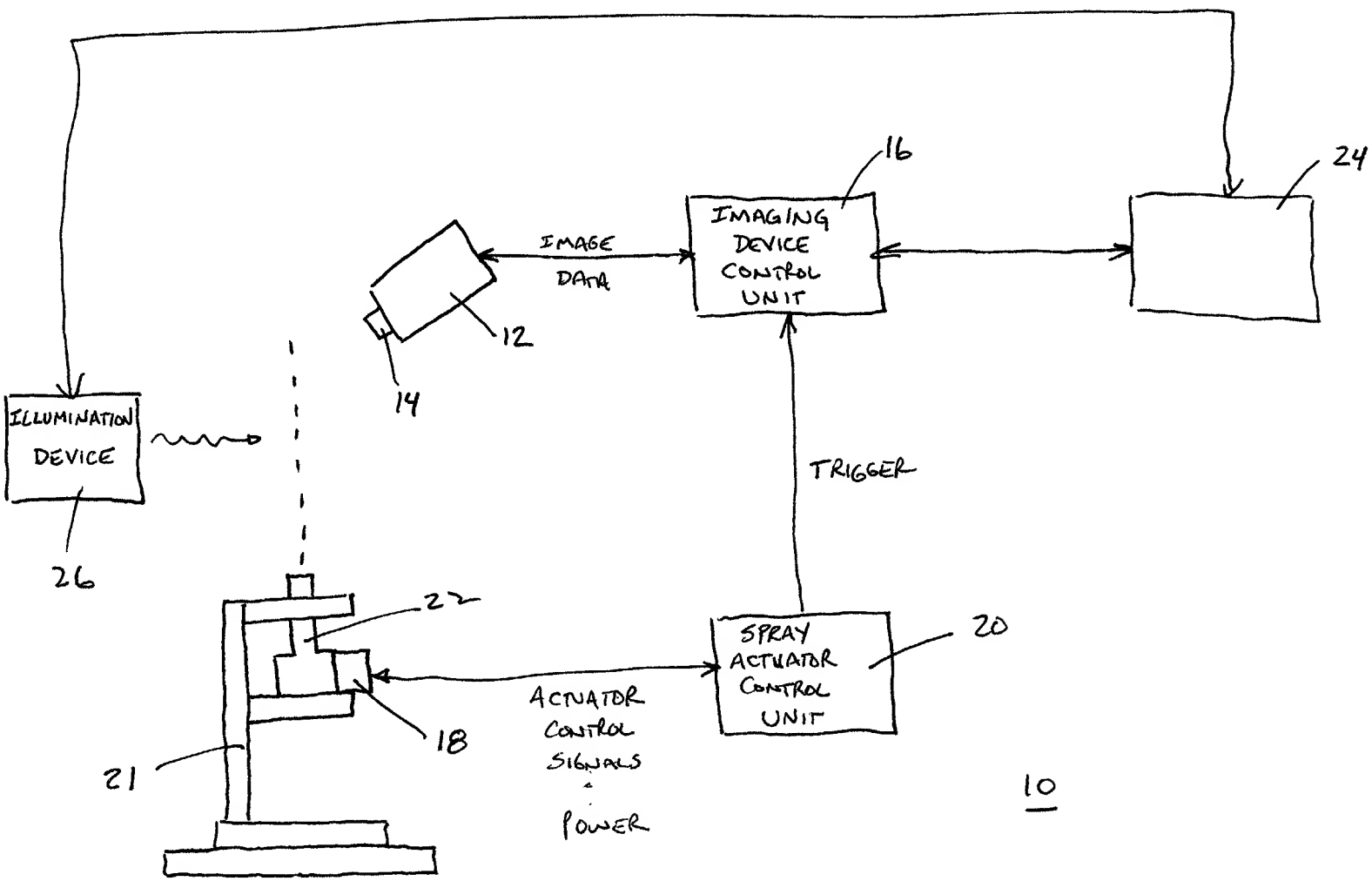
IMAGING DEVICE CONTROL UNIT
16
24
IMAGE DATA
12
14
ILLUMINATION DEVICE
26
TRIGGER
22
SPRAY ACTUATOR CONTROL UNIT
20
ACTUATOR CONTROL SIGNALS + POWER
18
21
10

FIG. 1

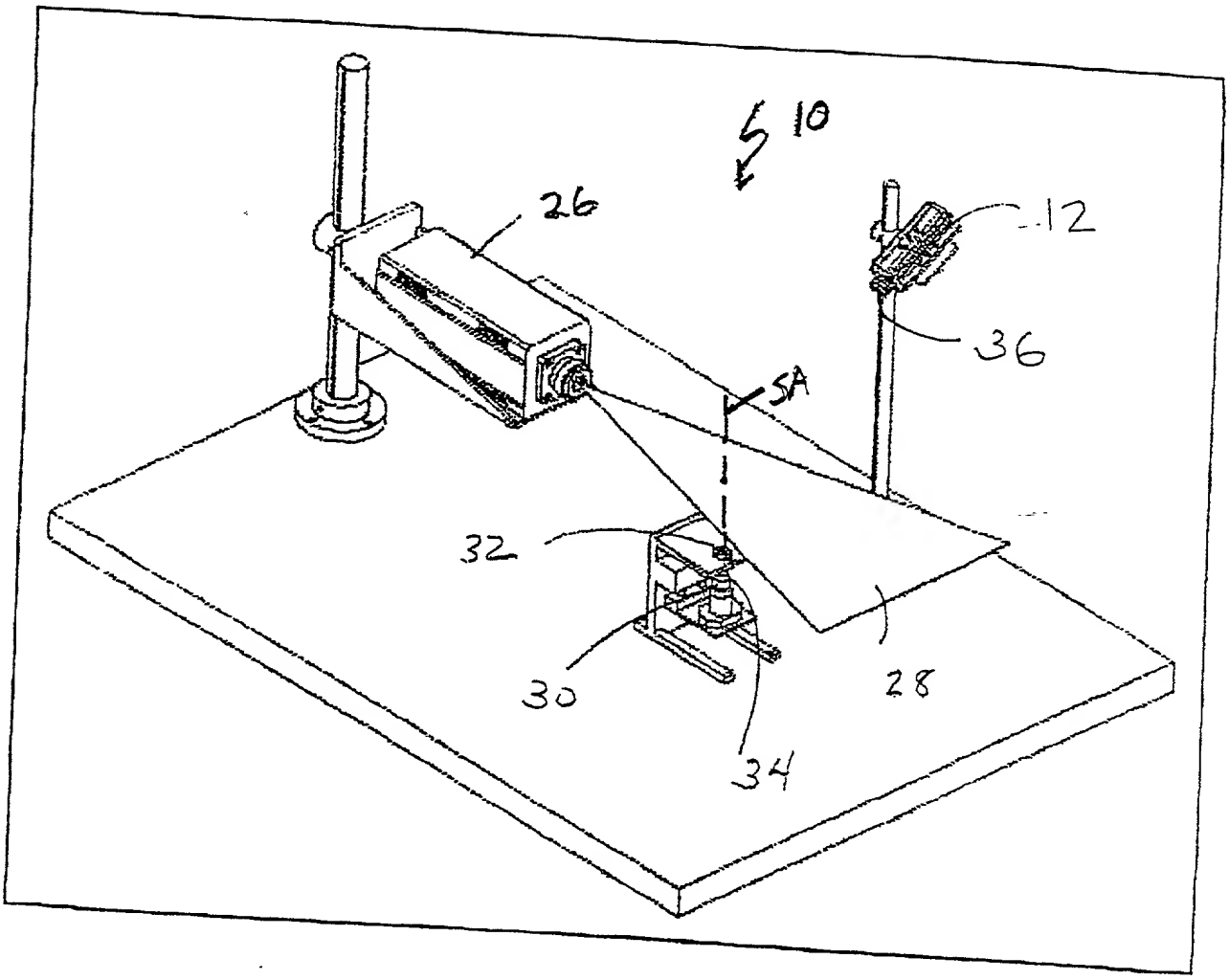

FIG. 2

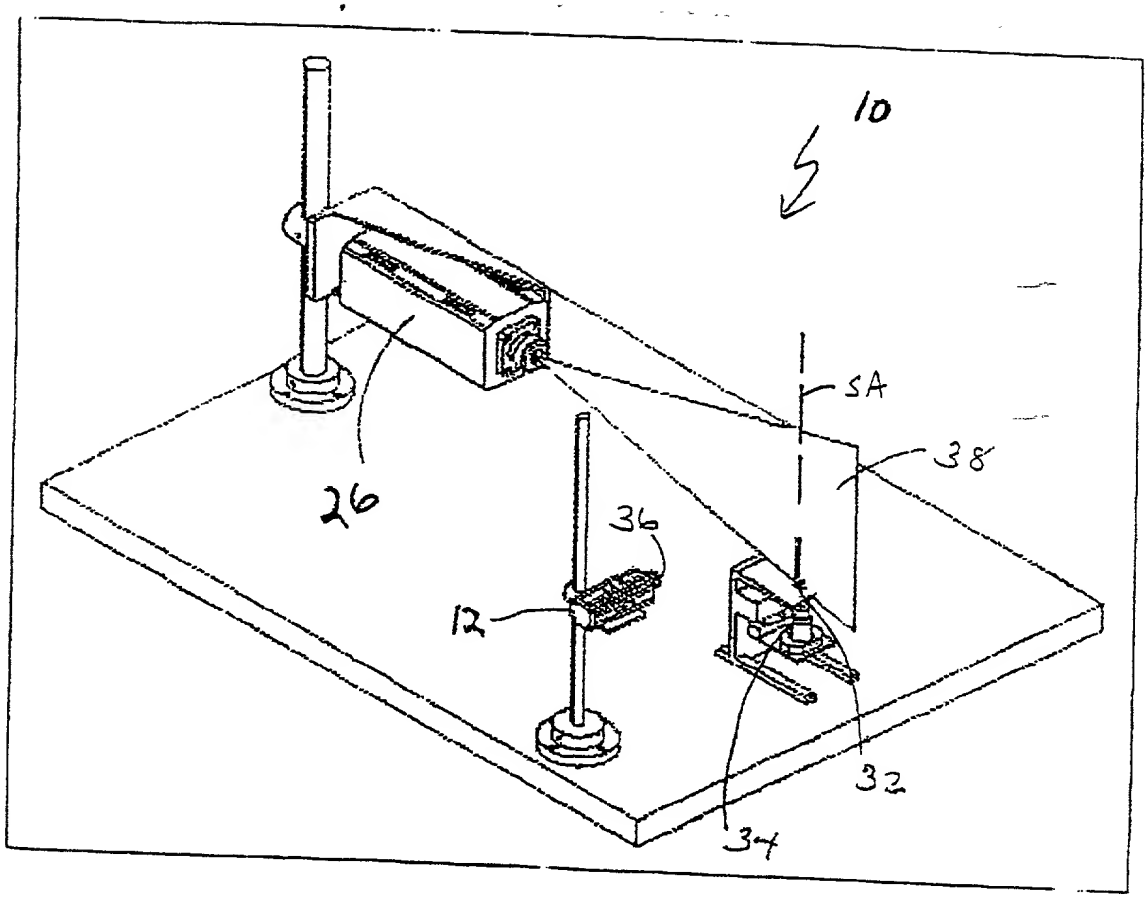

FIG. 3

Docket No.
56320-014

Declaration and Power of Attorney For Patent Application

English Language Declaration

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name,

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

SPRAY DATA ACQUISITION SYSTEM

the specification of which

(check one)

☒ is attached hereto.

☐ was filed on _____ as United States Application No. or PCT International Application Number _____

and was amended on _____

(if applicable)

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119(a)-(d) or Section 365(b) of any foreign application(s) for patent or inventor's certificate, or Section 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate or PCT International application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application(s)			Priority Not Claimed
_____	_____	_____	☐
(Number)	(Country)	(Day/Month/Year Filed)	
_____	_____	_____	☐
(Number)	(Country)	(Day/Month/Year Filed)	
_____	_____	_____	☐
(Number)	(Country)	(Day/Month/Year Filed)	

I hereby claim the benefit under 35 U.S.C. Section 119(e) of any United States provisional application(s) listed below:

60/149,281	08/17/99
(Application Serial No.)	(Filing Date)
(Application Serial No.)	(Filing Date)
(Application Serial No.)	(Filing Date)

I hereby claim the benefit under 35 U. S. C. Section 120 of any United States application(s), or Section 365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of 35 U.S.C. Section 112, I acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, C. F. R., Section 1.56 which became available between the filing date of the prior application and the national or PCT International filing date of this application:

(Application Serial No.)	(Filing Date)	(Status) (patented, pending, abandoned)
(Application Serial No.)	(Filing Date)	(Status) (patented, pending, abandoned)
(Application Serial No.)	(Filing Date)	(Status) (patented, pending, abandoned)

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. *(list name and registration number)*

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